# 4.0 METEOROLOGICAL MONITORING

Environmental protection activities, including the assessment of impacts of planned and unplanned airborne releases on public health and safety and the demonstration of compliance with applicable Federal, State, and local laws, regulations, and Orders, require meteorological information representative of conditions at DOE facilities (sources).[a] This information is needed to assess the transport, diffusion, and deposition of materials released to the atmosphere by a DOE facility. It is also important in the design of environmental monitoring networks.

Each DOE site (facility)[a] *should** establish a meteorological monitoring program that is appropriate to the activities at the site, the topographical characteristics of the site, and the distance to critical receptors. The scope of the program *should** be based on an evaluation of the regulatory requirements, meteorological data needed for impact assessments, environmental surveillance activities, and emergency response. For each site, the factors considered *should* include the following: the magnitude of potential source terms, possible pathways to the atmosphere, distances from release points to critical receptors, and proximity of the site to other DOE facilities. The site's meteorological program *should** be documented in a meteorological monitoring section of the Environmental Monitoring Plan (DOE 5400.1).

The type of meteorological information required by DOE facilities is not explicitly stated in laws, regulations, or DOE Orders. However, there is implicit recognition in regulations and directives of the type of information required. Meteorological considerations, which characterize atmospheric dispersion conditions, are an integral part of the dose assessment capabilities for both planned and unplanned releases. For example, 40 CFR Part 61.93, "National Emission Standards for Hazardous Air Pollutants; Standards for Radionuclides," states in part:

> Compliance with this standard will be determined by calculating the dose to members of the public at the point of maximum annual air concentration in an unrestricted area where any member of the public resides or abides.

In general, DOE sites will be required to have onsite measurements of wind direction, wind speed, and atmospheric stability available to evaluate atmospheric dispersion in the vicinity of facilities and to perform the required dose calculations specified in 40 CFR Part 61. Large, multifacility sites and those sites where one monitoring site location is inadequate to represent atmospheric conditions for transport and diffusion computations are required to establish monitoring programs that include additional meteorological measurements and measurements at more than one location to adequately evaluate transport and diffusion of effluents. This section provides guidance in selection and operation of meteorological instrumentation to obtain the required information.

---

(a) DOE usage of the terms "site" and "facility" is considered equivalent to 40 CFR Part 61 usage of the terms "facility" and "source."

Some sites may choose to establish a meteorological program that makes use of meteorological measurements obtained from offsite sources such as the National Weather Service. For data from an offsite source to be acceptable, the data *should** be representative of conditions at the DOE facility and provide statistically valid data consistent with onsite monitoring requirements. A determination of the acceptability of offsite data *should* be made by a qualified meteorologist.

Specific meteorological information requirements for each facility *should** be based on the magnitude of potential source terms, the nature of potential releases from the facility, possible pathways to the atmosphere, distances from release points to critical receptors, and the proximity of other DOE facilities. Dose assessment includes estimation of the transport, diffusion, and deposition of material released to the atmosphere. Methods that are appropriate for estimating transport and diffusion at a facility depend on the type, size, and location of the facility.

Meteorological information requirements for facilities *should** be sufficient to support environmental monitoring and surveillance programs. For example, meteorological information is required in the selection of locations for monitoring stations if monitoring is to take place at the projected points of maximum impact of a facility. The EPA (EPA-450/278-027R) provides useful guidance for the selection or prediction of the point or points of maximum impact.

The meteorological monitoring program requirements that need to be incorporated into the radiological effluent monitoring and environmental surveillance programs at a DOE site are presented in the summary.

## 4.1 METEOROLOGICAL PROGRAM BASIS

The principal use of meteorological data at DOE sites is to characterize atmospheric dispersion conditions. Such characterization is necessary to assess

- potential consequences of radiological releases from projected new or modified facilities
- consequences of actual routine radiological releases from existing facilities to demonstrate compliance with applicable regulations and standards
- consequences of actual accidental radiological releases.

### 4.1.1 Calculations for Dose Assessment

Atmospheric dispersion calculations used for dose assessment vary in sophistication and complexity from relatively simple computations to extensive computations that require the use of computers. Similarly, the meteorological data required for the calculations range from essentially none, for some of the simple techniques, to extensive data sets for some of the computer-intensive techniques. Use of the AIRDOS-EPA model currently referred to as CAP-88 or an EPA-approved alternative (40 CFR Part 61.93) is required to demonstrate compliance with 40 CFR Part 61. The meteorological input to the AIRDOS-EPA model includes the joint-frequency distribution of wind direction and atmospheric stability, and an average wind speed for each combination of wind direction and stability. The model also requires an average mixing-layer depth and an average temperature.

### 4.1.2 Calculated Atmospheric Transport and Diffusion

The meteorological monitoring program for each DOE site *should** provide the data for use in atmospheric transport and diffusion computations that are appropriate for the site and application. Before any model is deemed appropriate for a specific application, the assumptions upon which the model is based *should** be evaluated and the evaluation results documented. For example, assumptions that are reasonable in models used to demonstrate compliance with annual average concentration standards might not be reasonable in models used for emergency-response applications.

Use of simple compliance assessment techniques (NCRP Commentary 3), which are based on conservative assumptions and use little or no meteorological data, could be sufficient for some DOE sites. Meteorological programs for sites where onsite meteorological measurements are not required *should** include a description of climatology in the vicinity of the site and *should** provide ready access to representative meteorological data. Data from offsite sources, such as the National Weather Service, the Federal Aviation Administration, or military installations, can be used in these situations if the meteorological instruments are well-maintained and the data are readily available and representative of conditions at the site.

### 4.1.3 Use of Realistic Models

As the maximum magnitude of potential releases from a facility increases, the use of more realistic models is necessary to assess the consequences of the releases or demonstrate compliance with laws, regulations, and Orders. Potential release modes, distances from release points to receptors, and meteorological conditions *should** be considered in assessments for DOE facilities required to take onsite measurements. Computational techniques based on straight-line Gaussian models [e.g., AIRDOS-EPA (EPA 520/1-79-009)] are appropriate for facilities that are located in simple topographic settings. Straight-line Gaussian models are described in detail in many reports, including two in Meteorology and Atomic Energy - 1968 (Gifford 1968; Slade 1968), three in Atmospheric Science and Power Production (Barr and Clements 1984; Randerson 1984a,b), and one in GENII (Napier et al. 1988) As a minimum, these models require specification of wind direction, wind speed, and atmospheric stability. They may require the specification of mixing-layer thickness. If the models estimate deposition, they could require information on precipitation, and if the models compute plume rise for stack releases, the ambient air temperature could be required. Where appropriate, onsite measurements (e.g., tracer gas studies) could be used to help model atmospheric transport and diffusion and could also aid in model selection.

Straight-line Gaussian models are not appropriate for facilities that are located in valleys, near coasts or mountains, and on large sites. In these settings, strictly applied straight-line Gaussian models could underestimate the consequences of a release, as well as incorrectly identify locations where significant consequences occur. Trajectory models provide more realistic assessments in these settings. If AIRDOS-EPA or another EPA-approved straight-line model is used to demonstrate compliance with 40 CFR Part 61.93 for a facility located in complex terrain, an additional dose assessment *should* be made using a procedure that realistically accounts for temporal and spatial variations in atmospheric conditions and release rates.

Trajectory models (NUREG/CR-0523; EPA-600/8-84-207; EPA-600/8-86-024; NUREG/CR-3344; NUREG/CR-4000) treat atmospheric transport and diffusion as separate processes. This additional complexity is necessary to consider spatial and temporal variations of the atmosphere. These models generally require the same types of meteorological data as the straight-line models. However, to make full use of their capabilities to characterize spatial variations, use of meteorological data from more than one location is necessary. In addition, input to trajectory models is generally a series of hourly meteorological observations that include wind direction and speed, stability, temperature, and mixing-layer depth, rather than sets of frequency distributions.

## 4.2 DIFFUSION COEFFICIENTS

Gaussian straight-line and trajectory models make use of diffusion coefficients (commonly referred to as $\sigma_Y$ and $\sigma_Z$) to describe the spread of plumes. These coefficients are generally estimated on the basis of an atmospheric stability class and the distance the material has traveled since its release. The turbulence that causes diffusion is related to atmospheric stability; stability classes are used to permit climatological summarization of data. Gifford (1976) discusses various methods for determining diffusion coefficients.

### 4.2.1 Stability Estimation

Routine meteorological measurements by the National Weather Service and other organizations typically do not include the direct measurement of atmospheric stability or the determination of stability classes. Instead, a method of estimating stability classes based on wind speed and cloud cover (Gifford 1961; Pasquill 1961; Turner 1964; PHS Publication 999-AP-26) can be used to estimate stability classes from routine National Weather Service meteorological observations. The meteorological data required include cloud cover, ceiling height, and wind speed.

### 4.2.2 Methods of Determining Stability Class

Common methods of determining stability class from onsite meteorological measurements include the use of vertical temperature gradient, standard deviation of the wind direction ($\sigma\theta$), and the standard deviation of the elevation angle of the wind ($\sigma\phi$). The methods using the temperature gradient and $\sigma\theta$ are described in the American National Standards Institute's ANSI/ANS-2.5-1984 and

NRC Regulatory Guide 1.23. Irwin (1980) discusses the $\sigma\theta$ and $\sigma\phi$ methods and presents a method that uses both $\sigma\theta$ and wind speed. This method is described in the EPA air quality modeling guidelines (EPA-450/2-78-027R).

### 4.2.3 EPA-Preferred Methods

The method of estimating stability classes described by PHS Publication 999-AP-26, used with onsite data, is preferred by the EPA (EPA-450/2-78-027R) for air quality modeling. If the data required by this method are not available, the EPA order of preference is 1) the $\sigma\phi$ method using onsite data; 2) the $\sigma\theta$ wind-speed method using onsite data; and 3) the Turner method using onsite wind speed, and cloud cover and ceiling height from a nearby, representative National Weather Service site. The temperature gradient method of determining stability class has been held by ANSI and the NRC to be acceptable for estimating both the horizontal and vertical diffusion coefficients, while the $\sigma\theta$ method has been held to be acceptable only for estimating the horizontal diffusion coefficient.

### 4.2.4 Atmospheric Turbulence Measurements

Numerous studies (NUREG/CR-0798; Lague et al. 1980; Lalas et al. 1979; Luna and Church 1972; Mitchell 1982; Sedefian and Bennett 1980; Skaggs and Robinson 1976; Weil 1979) have compared methods of determining stability classes. When hourly data are examined, the results of the various methods are not highly correlated. Consequently, the use of stability classes *should* be avoided when assessing the effects of short duration releases that take place at a known time. Diffusion coefficients for this application can be estimated directly from atmospheric turbulence measurements (Hanna et al. 1977; Irwin 1983; Pasquill 1979; Ramsdell et al. 1982). Turbulence data for estimating the horizontal diffusion coefficient can be obtained from the same sensors used for wind direction and speed measurements with additional signal processing. Obtaining turbulence data for estimating vertical diffusion coefficients generally requires special but readily available sensors.

## 4.3 PLUME RISE AND BUILDING WAKES

Evaluation of the consequences of releases through free-standing stacks may include consideration of the effective plume rise due to momentum and buoyancy. Generally accepted methods for estimating plume rise are described by Briggs (1984), although EPA models estimate plume rise using earlier methods developed by Briggs and others (EPA-450/2-78-027R). Estimation of plume rise requires air temperature and wind speed at release height, vertical temperature gradient, and an estimate of the mixing-layer thickness. It also requires information on the stack dimensions, stack flow, and effluent temperature. Basic straight-line and trajectory plume models assume (except in computation of plume rise) that material is released from a point source. When it is necessary to evaluate the consequences of a release on receptors near the release point, the basic models *should* be modified to account for deviations from this assumption. Diffusion in the vicinity of buildings and other obstacles may result in the need for model modification to account for wake effects. Wake effects are discussed by Hosker (1984) and EPA-450/4-86/005a.

For ground-level releases, the standard modifications increase the diffusion coefficients on the basis of dimensions of the structure. For elevated releases, the modifications adjust the height of release based on the ratio between the initial vertical velocity of the effluent and the wind speed at release height.

## 4.4 METEOROLOGICAL MEASUREMENTS

Meteorological measurements *should** be made in locations that, to the extent practicable, provide data representative of the atmospheric conditions into which material will be released and transported. A meteorologist or other atmospheric scientist with experience in atmospheric dispersion and meteorological instrumentation *should* be consulted in determining whether onsite data are required and, if so, in selecting measurement locations and in the design and installation of the meteorological measurement system. Factors to be considered in selecting measurement locations and installation of the instruments include the prevailing wind direction, topography, and obstructions. Also, any special meteorological monitoring requirements imposed by other agencies (outside the DOE) *should* be taken into consideration when designing meteorological measurement systems and establishing measurement locations. The instruments used in the monitoring program *should** be capable of continuous operation in the expected range of atmospheric conditions at the facility. The frequency of thunderstorms, icing, or other chemical or physical agents that may cause damage or deteriorate performance *should* be considered in selecting specific sensors and designing the sensor installation. An uninterruptable power supply *should* be included in the system, and an alternate source of power *should* be available.

### 4.4.1 Location of Meteorological Measurements

Wind measurements *should** be made at a sufficient number of heights to adequately characterize the wind at potential release heights. In general, wind measurements *should* be made at a height of 10 m. If a vertical temperature difference is used to characterize atmospheric stability, the temperature difference *should* be determined over an interval of sufficient thickness to allow adequate determination of accepted stability classes. A 50-m thickness has been held acceptable (ANSI/ANS-2.5-1984; NRC Regulatory Guide 1.23) for this purpose. For surface releases, ANSI (ANSI/ANS-2.5-1984) and the NRC (Regulatory Guide 1.23) recommend a measurement of the temperature difference between 10 and 60 m. If releases are to be made through stacks that are taller than 60 m, ANSI and the NRC suggest that the temperature difference between the release height and the 10-m height be determined. Other necessary meteorological measurements *should* be made using standard instrumentation in accordance with accepted procedures. Standard meteorological measurement techniques are described by Mason and Moses (1984), and accepted procedures are outlined in ANSI/ANS-2.5-1984.

### 4.4.2 Instrument Mounting

Wind and temperature instruments mounted on towers may be placed on top of the towers or on booms extending to the side of the towers. Instruments mounted above a tower *should* be mounted on a mast extending at least one tower diameter above the tower. If instruments are mounted on booms extending to the side of a tower, the booms *should** be oriented in directions that minimize the potential effects of the tower on the measurements. Instruments mounted on booms *should** be at least two tower diameters from the tower, but *should* be positioned three to four tower diameters from the tower. The orientation of booms for wind instruments *should* be determined after considering the frequencies of all wind directions. Orientation of the booms on the basis of only the prevailing direction might not minimize tower effects. In some locations, placement of wind instruments on opposite sides of the tower could be necessary to obtain reliable wind data for all wind directions. Temperature sensors *should* be placed in aspirated radiation shields, and the shields *should* be oriented to minimize effects of direct and reflected solar radiation.

### 4.4.3 Measurement Recording Systems

The onsite meteorological measurement system *should* include two separate data-recording systems, and at least one of the systems *should* be digitally controlled. The other recording system may be digital or analog. In addition, the output of the instruments *should* be displayed in a location where instrument performance can be monitored on a regular basis. Digitally recorded data, except for $\sigma\theta$ and precipitation, *should* be averaged over at least 30 samples taken at intervals not to exceed 60 seconds. The time period represented by the averages *should* not be less than 15 minutes. A minimum of 180 instantaneous wind direction samples are *required* for estimation of $\sigma\theta$ and $\sigma\phi$. If strip charts are used as one of the recording systems, continuous-trace strip charts *should* be used for wind data; multipoint strip-chart recorders may be used for the remaining data. If properly located, the strip charts may be used for the data displays.

## 4.5 MEASUREMENT SYSTEM ACCURACY

The accuracies of the monitoring measurements *should* be consistent with the specifications set forth in either ANSI/ANS-2.5-1984, the version of ANSI/ANS-2.5 that is current when the monitoring system is designed, or guidance provided by the EPA if EPA guidance recommends more stringent specifications. System accuracy standards for digitally recorded data and instrument specifications contained in ANSI/ANS-2.5-1984 include the following:

| | |
|---|---|
| Wind direction | ±5° in azimuth with a starting threshold of 0.45 m/sec (1 mph). If the sensor is to be used to determine $\sigma\theta$, the damping ratio must be between 0.4 and 0.6, and the delay distance must not exceed 2 m. |
| Wind speed | ±0.22 m/sec (0.5 mph) for speeds less than 2.2 m/sec (5 mph); within 10% for speeds of 2.2 m/sec or greater, starting speed of less than 0.45 m/sec. |
| Temperature | ±0.5°C. |
| Temperature difference | ±0.15°C/50 m. |

| | |
|---|---|
| Precipitation | ±0.25 mm (0.01 in.) resolution, and within 10% for totals greater than 5 mm (0.2 in.). |
| Time | ±5 min. |

For analog data-recording systems, the allowable error limits for wind direction and speed are increased by 50%, and the acceptable error in time is increased to 10 minutes.

## 4.6 INSPECTION, MAINTENANCE, AND CALIBRATION

The meteorological monitoring program *should** provide for routine inspection of the data and scheduled maintenance and calibration of the meteorological instrumentation and data-acquisition system at a minimum, based on the calibration frequency recommendations of the manufacturers. Inspections, maintenance, and calibrations *should** be conducted in accordance with written procedures, and logs of the inspections, maintenance, and calibrations *should** be kept and maintained as permanent records. All systems *should* be calibrated semiannually, unless system performance indicates that more frequent calibrations are necessary. The instrument system *should** provide data recovery of at least 90% on an annual basis for wind direction, wind speed, those parameters necessary to classify atmospheric stability, and other meteorological elements required for dose assessment. Data recovery rates for other meteorological elements *should* be 90% on an annual basis.

## 4.7 SUPPLEMENTARY INSTRUMENTATION

The topographic setting of a facility and the distances from the facility to points of public access *should** be considered when evaluating the need for supplementary instrumentation. If meteorological measurements at a single location cannot adequately represent atmospheric conditions for transport and diffusion computations, supplementary measurements *should** be made. Full meteorological instrumentation is not required at a supplementary location. Supplementary instruments need measure only those elements that have significant spatial variation.

## 4.8 LARGE-SITE (MULTIFACILITY INSTALLATION) METEOROLOGICAL PROGRAMS

Many DOE facilities are located on large multifacility sites (e.g., Savannah River Laboratory, Oak Ridge National Laboratory, Idaho National Engineering Laboratory, and Hanford Site). These sites cover many square miles. As a result, spatial variations in meteorological conditions must be considered in evaluating transport and diffusion between the facilities and points of public access. A site-wide meteorological monitoring program *should** be established at each multifacility site to provide a comprehensive data base that can be used for all facilities located within the site. It is not necessary to establish a meteorological program for each individual facility.

Consequence assessments can be made for individual facilities using facility-specific source term and release characteristics and a common data base for the transport and diffusion analysis.

### 4.9 DATA SUMMARIZATION AND ARCHIVING

Data used in dose assessments *should* be collected as 15-minute averages for use in emergency response applications. The 15-minute averages can be combined into hourly averages for use in consequence assessments. The 15-minute data *should* remain readily available in a temporary archive for at least 24 hours. Then either the 15-minute or hourly averages *should* be stored for entry into a permanent archive and climatological summarization. These data *should* be examined and entered into the permanent archive at least monthly. Storage of the 15-minute or hourly data is necessary to develop an adequate data base for use with new assessment tools as they are developed. More frequent examination of the hourly data to detect problems in meteorological instrumentation or in the data acquisition system is recommended. Further guidance in meteorological data collection, processing, and archiving is presented by Crutcher (1984) and in various EPA documents (e.g., EPA-450/2-78-027R; Finkelstein et al. 1983).

### 4.10 METEOROLOGICAL DATA PROCESSING

Designing environmental surveillance programs, establishing compliance with regulations, and analyzing the consequences of potential or actual releases require information on a common set of meteorological elements. Typically these elements are wind direction, wind speed, air temperature and temperature gradient, and mixing-layer thickness. Although the individual applications could require data for a common set of meteorological elements, the format in which the data are required will vary by application and assessment procedure.

#### 4.10.1 Routine Releases

Assessment of potential consequences of routine radiological releases from projected new or modified facilities *should* be based on climatological data because the meteorological conditions at the time of release are unknown. If the postulated release is continuous, the analyses *should* be made using a joint frequency distribution of wind direction, wind speed, and atmospheric stability based on data from at least one annual cycle. When possible, the frequency distributions *should* be based on 5 or more years of data. This approach could also be used for intermittent releases if the releases occur randomly and with sufficient frequency to make the use of an annual-frequency distribution appropriate.

Assessments of the consequences of routine releases from existing facilities and demonstrations of compliance can also be made using climatological summaries, provided that a straight-line model is appropriate. Climatological summaries used in the evaluation of consequences of an actual release *should* be based on hourly data for the specific period of the release. For example, if a continuous release occurs from May 15 through June 26, the joint-frequency distribution *should* be based on the meteorological observations during that period. Where straight-line models are inappropriate, consequence assessments for routine releases and demonstrations of compliance *should* be made using a time series of hourly averaged data. These time series *should* include all supplementary data required to account for spatial as well as temporal variations in atmospheric conditions.

### 4.10.2 Accidental Releases (Off-Normal, Unusual Occurrence, or Emergency)

Consequence analyses for postulated accidental releases *should* be made for each downwind direction using conservative meteorological assumptions for each release scenario. For a ground-level release, these assumptions *should* include a low wind speed and stable atmospheric conditions; for elevated releases, a range of conditions *should* be evaluated because a moderate wind speed and neutral atmospheric conditions may be more conservative than a low wind speed and stable conditions. Straight-line Gaussian models could be appropriate for assessment of some postulated releases. Trajectory models could also be used if adequate data are available. The joint-frequency distribution and choices of meteorological conditions for the accident analyses *should* be based on a minimum of 2 years of hourly averaged data. However, if offsite data are used, the analyses may be based on 2 or more years of hourly observations made with well-maintained instrumentation.

Consequence assessments during the course of an emergency *should* be based on time series of actual and forecast atmospheric conditions. When necessary, data *should* be included in the time series to represent spatial variations in the atmospheric conditions. An averaging interval of 15 minutes has been accepted by the NRC as appropriate for data used in emergency response applications. This interval is consistent with the averaging interval specification in ANSI/ANS-2.5-1984. Instantaneous observations are too variable to be used with confidence, and hourly averaged values do not reflect changes in conditions in a timely manner for emergency response applications.

### 4.10.3 Data Needs

Assessment procedures have varying meteorological data needs and a precise format in which the meteorological data must be entered. The data needs and format for AIRDOS-EPA are set forth in EPA 520/1-79-009. Data needs for other EPA models are set forth in the individual documentation of the specific models and are summarized in EPA-450/2-78-027R. In addition to EPA models, there are DOE, NRC, and proprietary models that might be appropriate for consequence assessments. Data requirements for these models must be determined from model documentation.

## 4.11 QUALITY ASSURANCE

As they apply to meteorological monitoring, the general quality assurance program provisions described in Chapter 10 *should** be followed. Specific quality assurance activity requirements for the facility's meteorological monitoring program, sufficient to provide acceptable data recovery and accuracy, are to be contained in the Quality Assurance Plan associated with the facility. Guidance in quality assurance related to meteorological measurements and meteorological data processing may be found in Finkelstein et al. (1983).